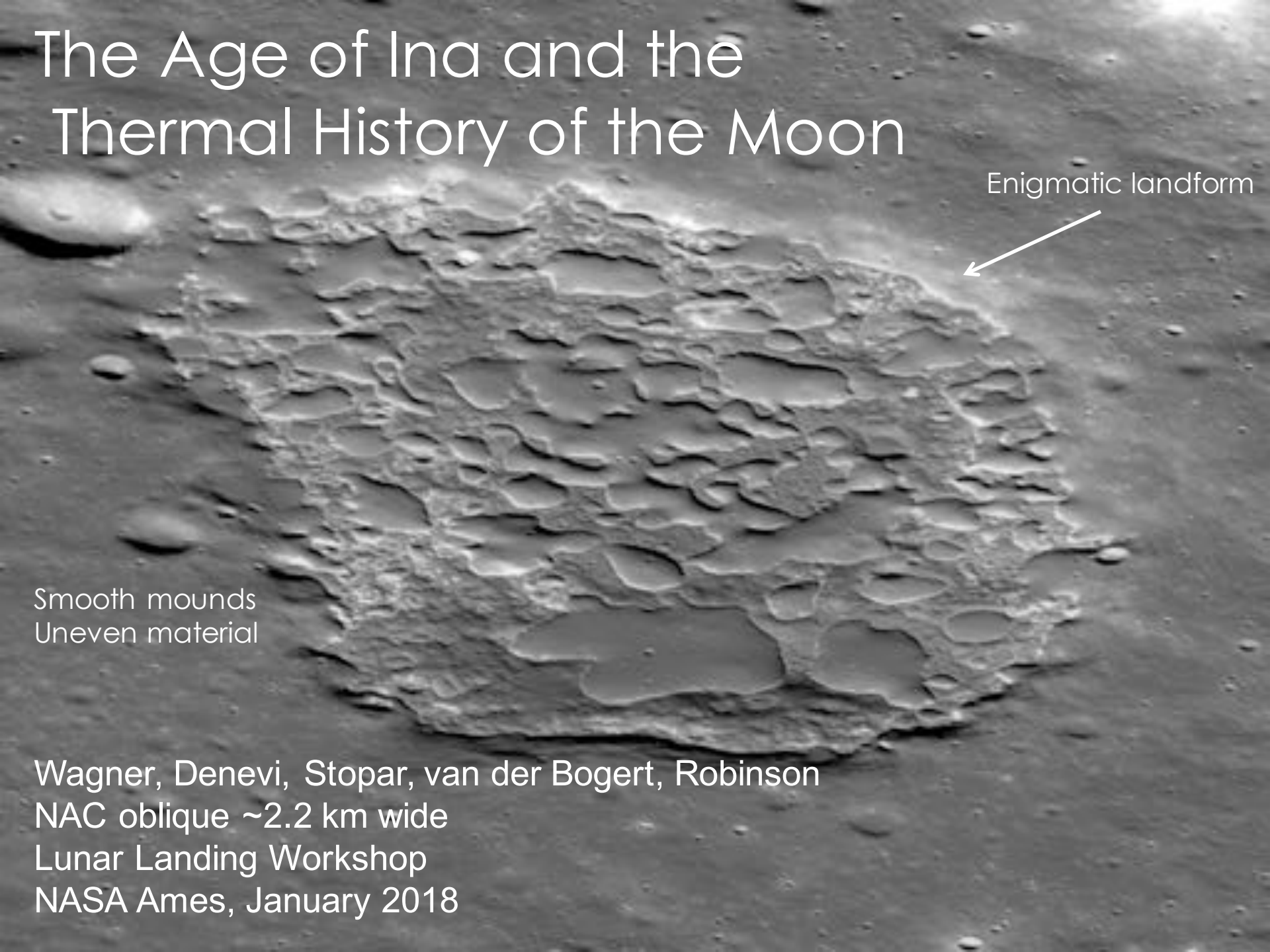
The Age of Ina and the Thermal History of the Moon



Wagner, Denevi, Stopar, van der Bogert, Robinson

NAC oblique ~2.2 km wide

Lunar Landing Workshop

NASA Ames, January 2018

Evidence for basaltic volcanism on the Moon within the past 100 million years

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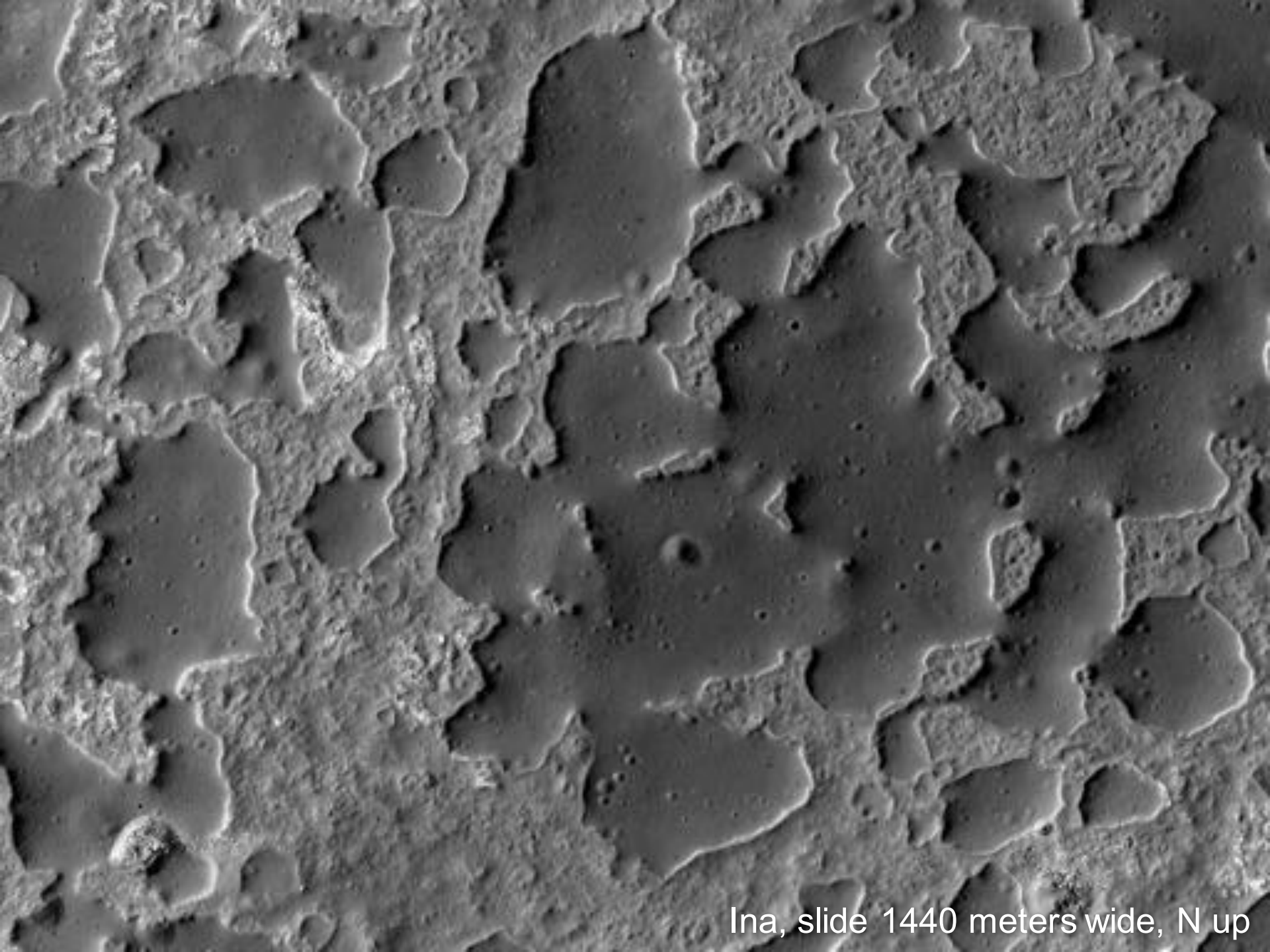
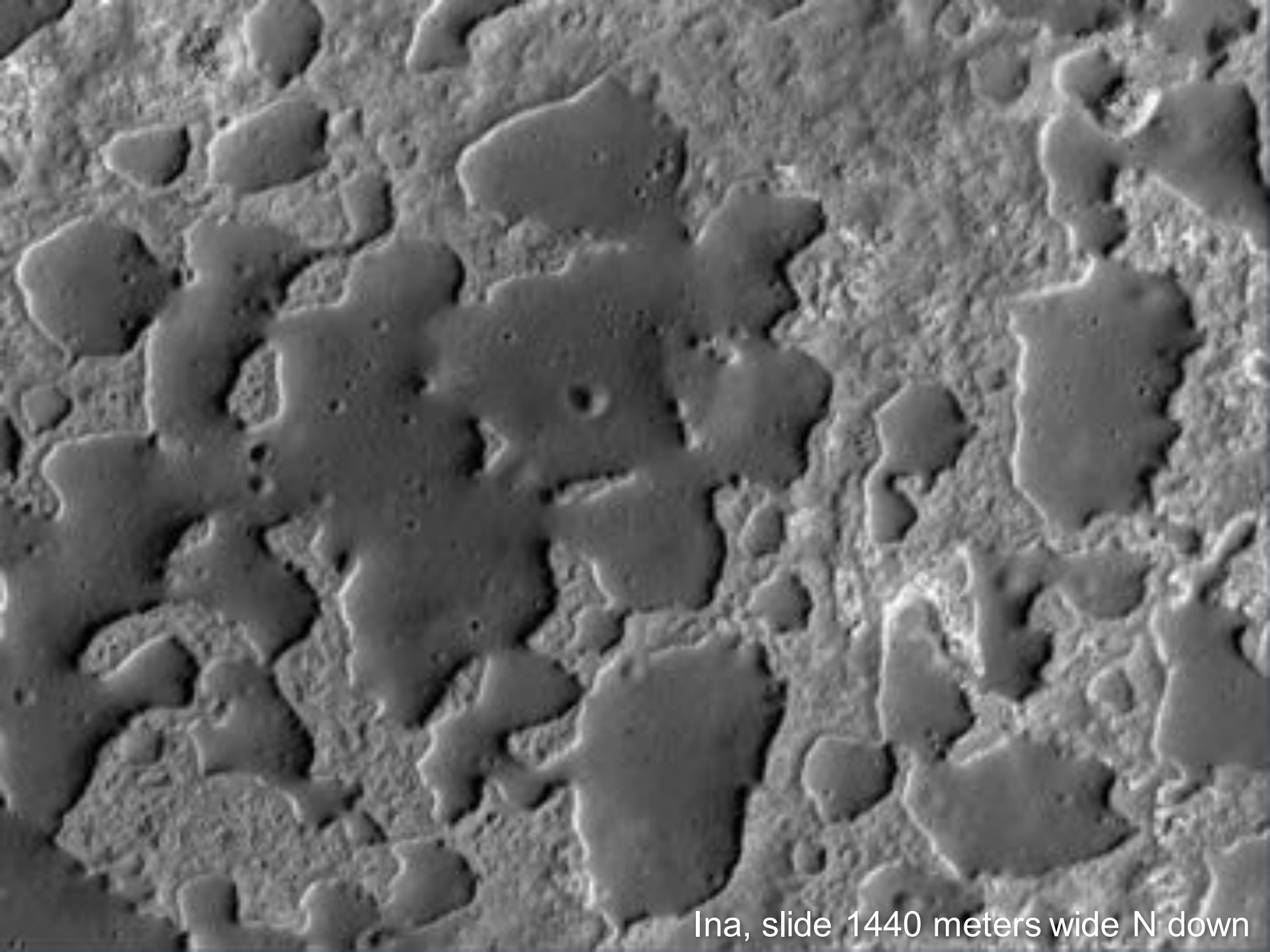
- NAC provided 50 cm pixel scale images
- 2 m scale topography
- Images allowed CSFD down to 5 m scale
- Model age from CSFD indicates formation age <100 my for smooth mounds (even fewer craters on uneven material)
- CSFD showed no equilibrium diameter
- Steep edges and meter scale landforms consistent with young age
- Age <100 my is an extraordinary result, is it correct?


Ina, slide 1440 meters wide, N up


Ina, slide 1440 meters wide N down

Ina

New Model IMP Formation

Wilson and Head, JVGR, 2017
Le Qiao et al, Geology 2017

- SM formed as magmatic foam erupted through heavily fractured and porous crust
- Magmatic "foam" 75% to 95% porosity (very low strength material)

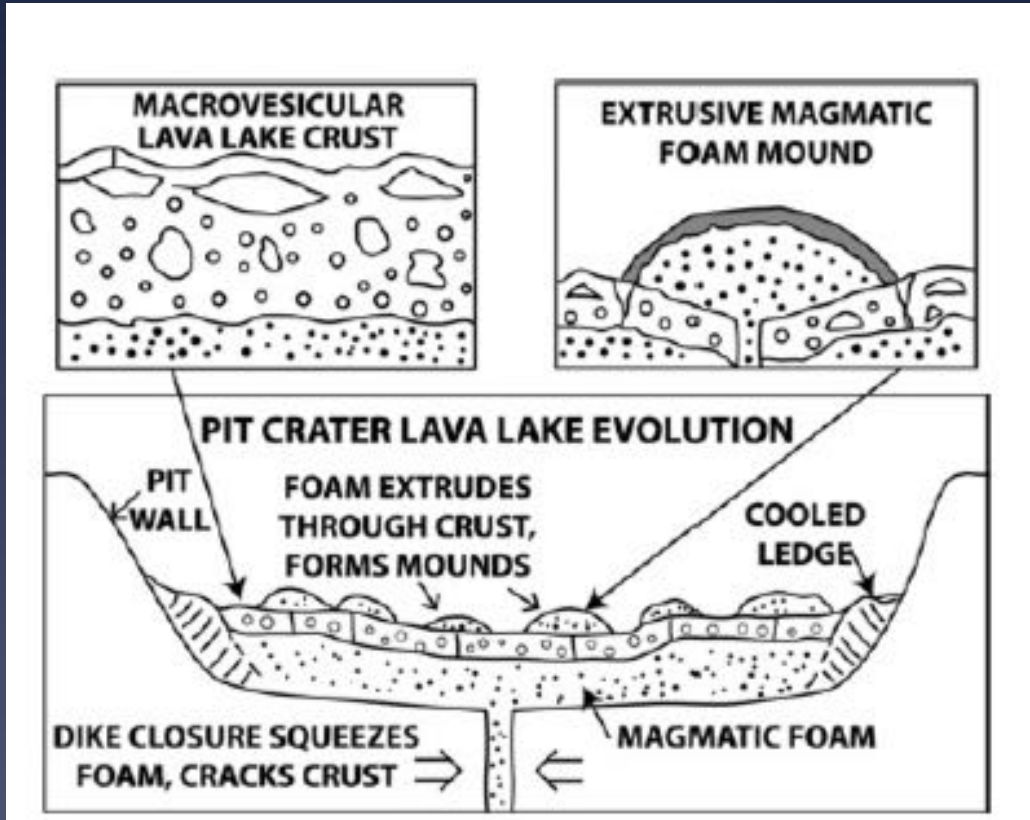


Figure 3. Cross section of the waning stage process of magmatic foam emplacement in the Ina summit pit crater (Moon).

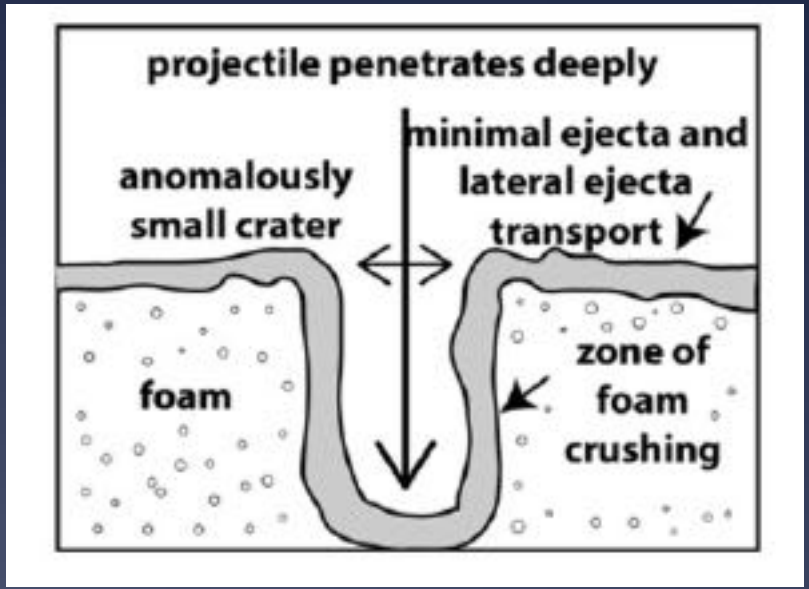
Qiao et al, 2017

Le Qiao et al Age Estimate

- Count craters on shield area just south of Ina as a comparison point (3.5 by model age)
- Correct crater population on smooth mounds diameters for strength difference
  - Lab experiments show excavated mass vs projectile mass can decrease 100x in highly porous targets
  - Derived a 3x reduction of crater size based on 100x
- Derived model age from count taken *on shield* after dividing diameters by 3. Model age = 85 my
- Conclusion: after correcting for target materials age is actually 3.5 by

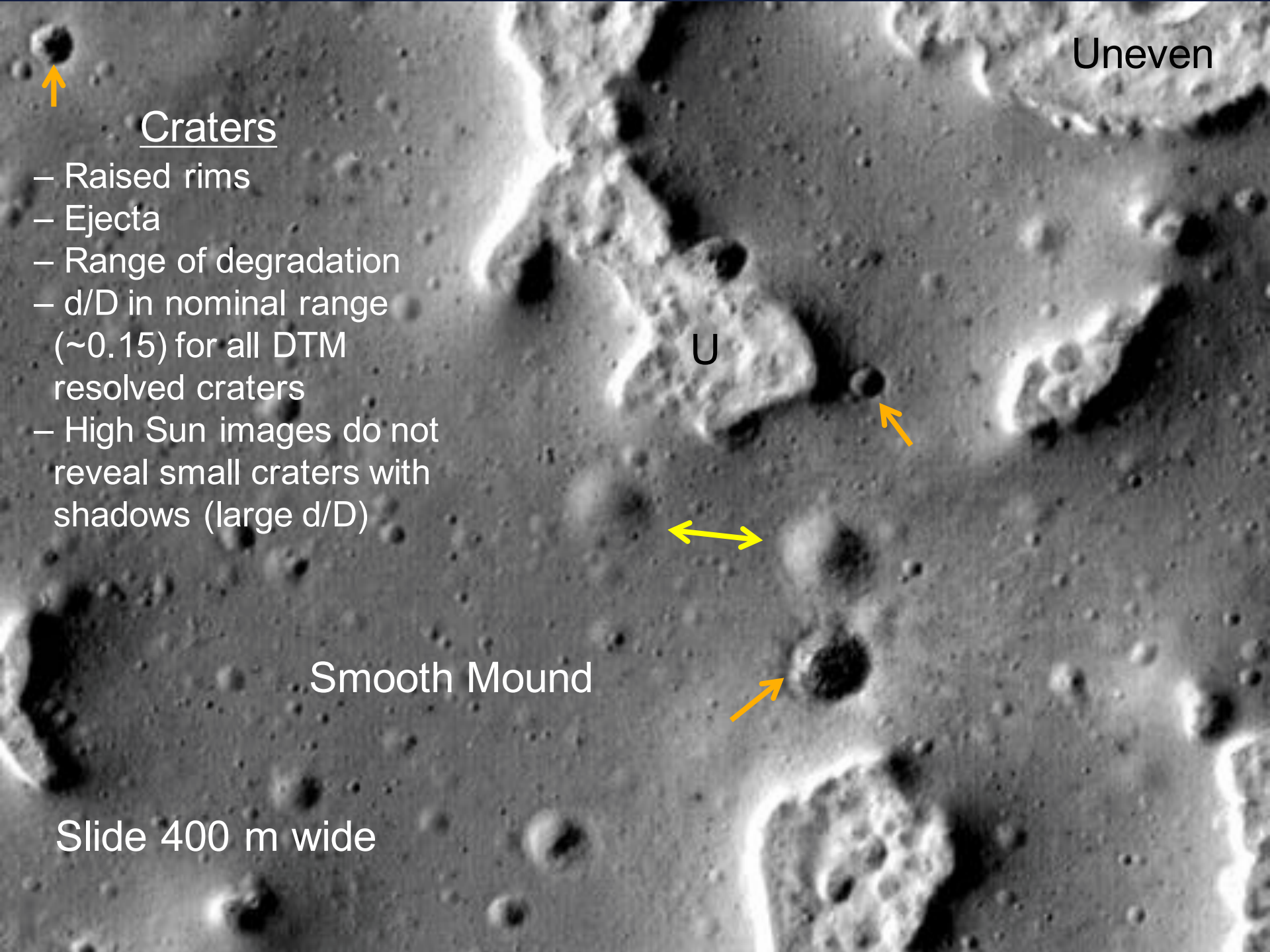
Crater Formation Model

- Wilson and Head predict that impact craters formed in foamy material will have relatively large depth to diameters due to crushing rather than excavating (aerogel effect)
- Le Qiao et al. decreased diameters from nearby 3.5 by area by 3x to account for small deep craters and computed an age of 85 my for Ina - was this valid?
- Test: Are the morphologies of craters on the mounds consistent with this model?

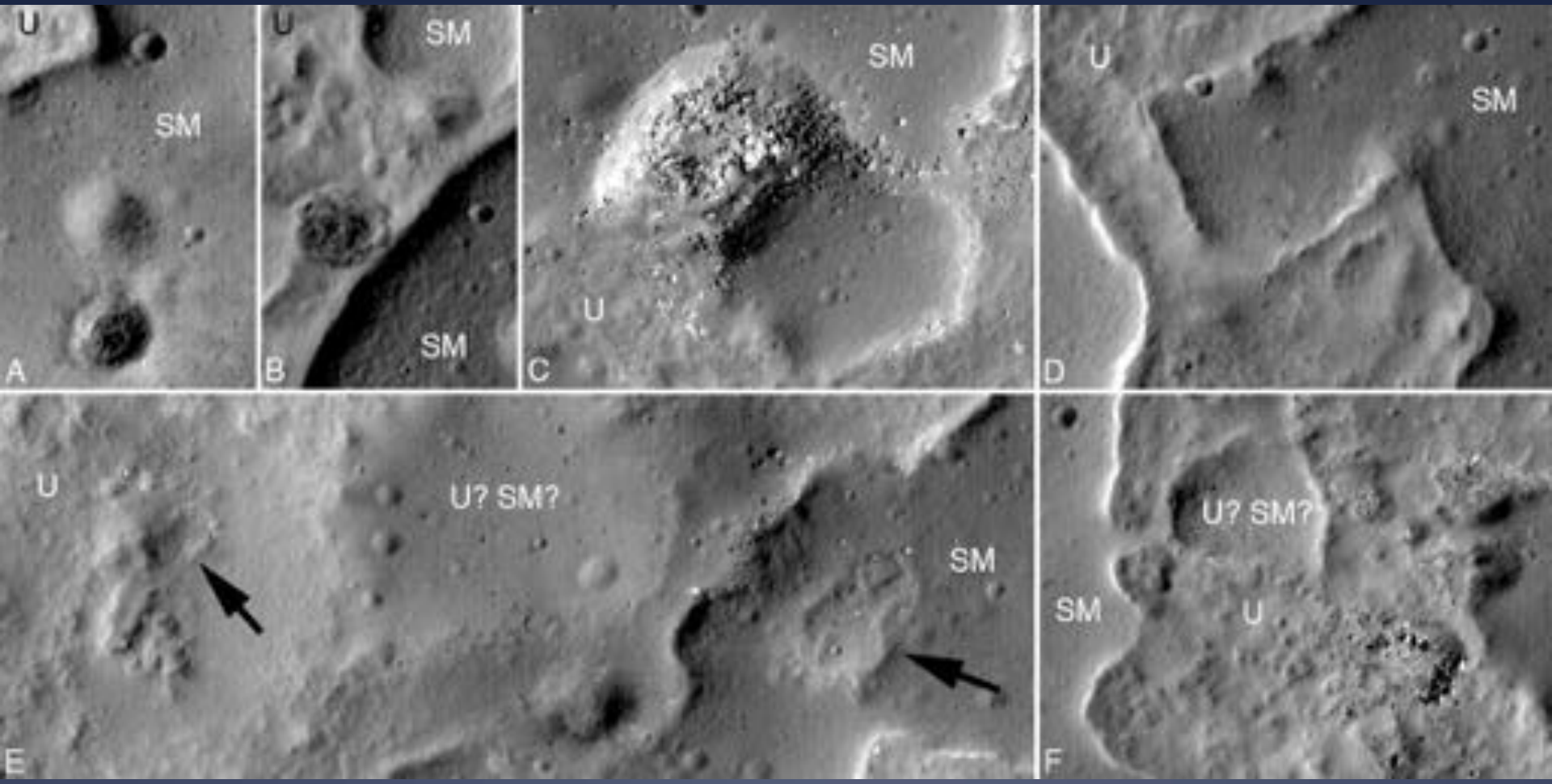


From Wilson and Head 2017

d/D from cartoon ~2.3
Lets call that a way upper limit
Look at 0.67 as baseline
Normal craters <0.15


Craters
– Raised rims
– Ejecta
– Range of degradation
– d/D in nominal range (~0.15) for all DTM resolved craters
– High Sun images do not reveal small craters with shadows (large d/D)
Uneven
U
Smooth Mound
Slide 400 m wide

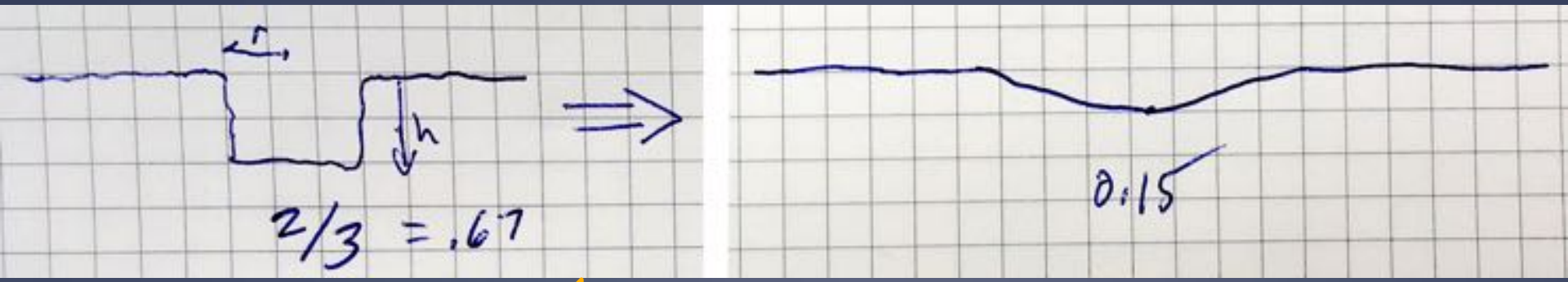
Ina Landforms



M175246029, 40 cm pixels, (D) 323 m wide, inc 46˚ , phase 74˚ , SM = smooth mounds, U= uneven materials, arrows in (E) indicate proposed flow morphologies

Original D to Current D

- Wilson and Head model predicts deep cylindrical craters (d/D >2?) that degrade quickly
- Conventional wisdom: As craters degrade their diameters increase and depths decrease (d/D decreases)
- Ex: Original d/D of 0.67 degrades to <0.15. In this case model ages must correct measured diameter back to original diameter
  - d/D original: 0.50 0.67 1.00 → 2.2x 2.4x 2.7x D growth
- Original d/D of 2 requires D growth >3 as crater "ages"

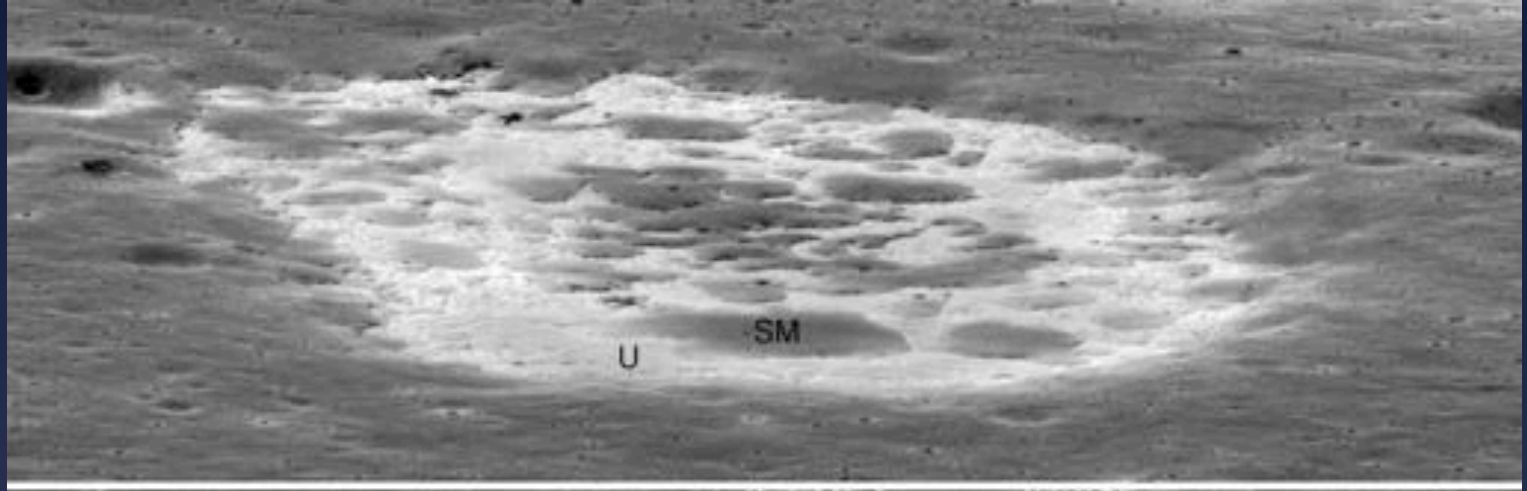


Diameter Correction

- Need to know original d/D to accurately compute model ages
  - Assuming 0.67* original d/D - the diameter (D) has increased by 2.4x through degradation
  - Assuming 2.0 original d/D - the diameter (D) has increased by 3x through degradation
- Confusing!
  - Braden et al propose that crater diameter increases for craters formed in loose regolith vs rock
  - Le Qiao et al and Wilson-Head propose that crater diameter decreases for craters formed in highly porous (foam) targets based on lab tests and models

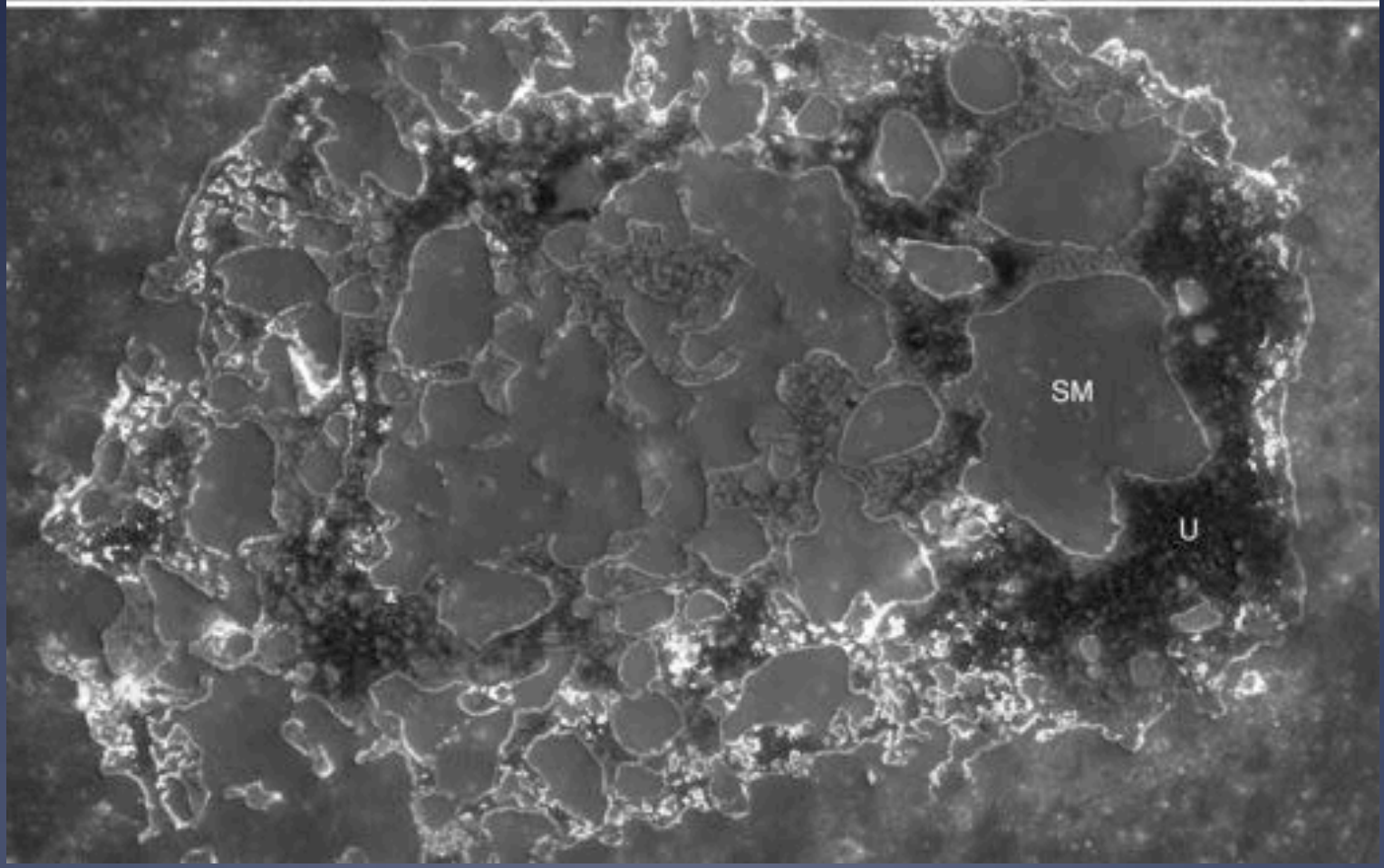
*Just to be very conservative, Wilson-Head figure closer to d/D = 2

Large phase Ina east-to-west oblique view (phase 106°, inc 34°, ema 75°)



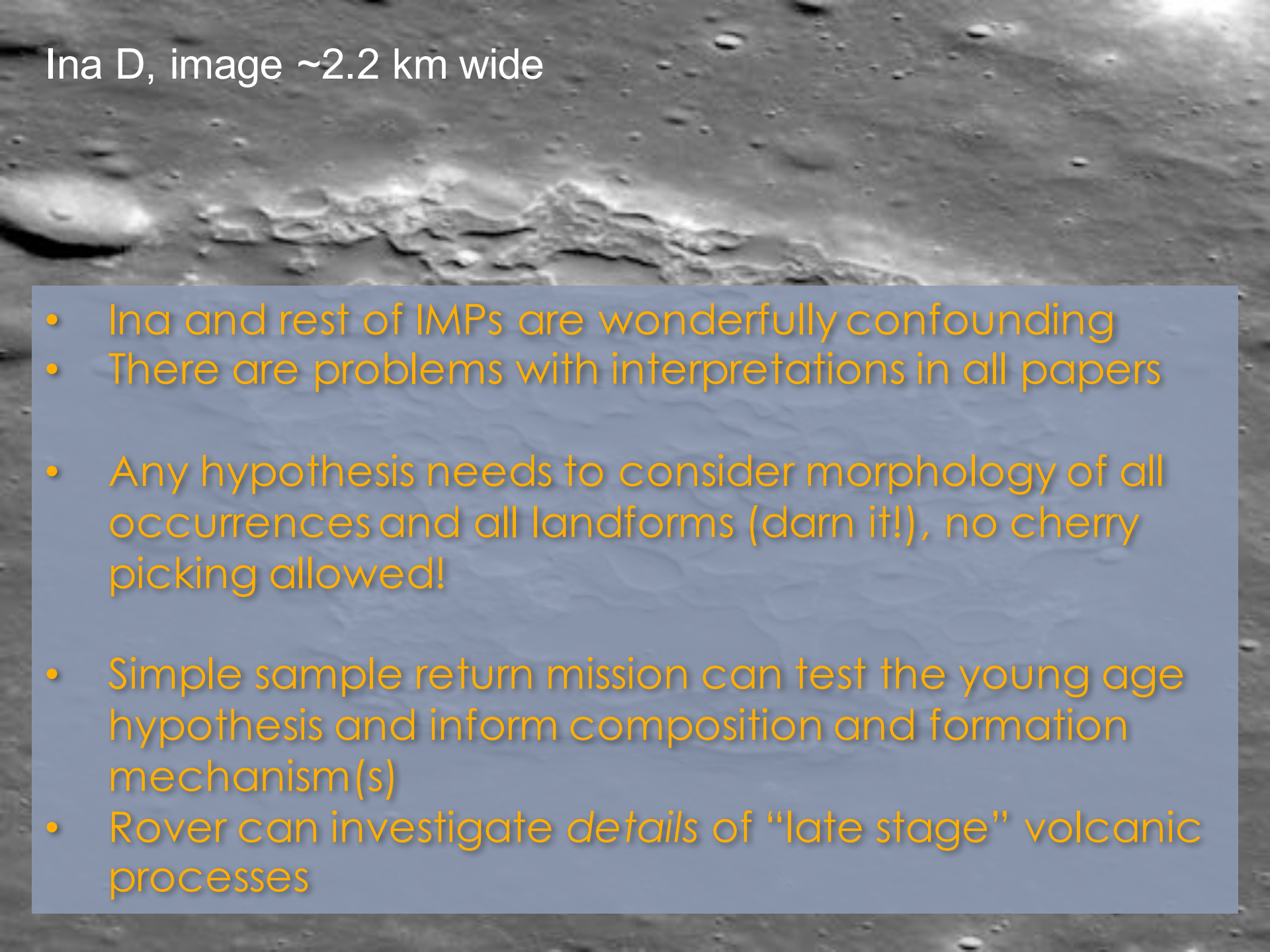
U is relatively more forward scattering (and or smoother) than SM or surrounding mare

Small phase image, ~2700 m west-to-east (phase 11°, inc 21°, ema



Outstanding Issues

- Braden et al: Why do the Smooth Mounds not look like very young impact melt deposits (cracks, weird craters)
- Braden et al: What is the nature of the uneven unit? Why so few craters?
- Qiao et al + W/H: crater morphology
- Qiao et al + W/H: lifetime of materials with porosity approaching 90%
- Qiao et al + H/W: 3.5 by survival of meter scale landforms



- Ina and rest of IMPs are wonderfully confounding
- There are problems with interpretations in all papers

- Any hypothesis needs to consider morphology of all occurrences and all landforms (darn it!), no cherry picking allowed!

- Simple sample return mission can test the young age hypothesis and inform composition and formation mechanism(s)
- Rover can investigate *details* of "late stage" volcanic processes